CHAPTER 8

UNDERWATER INSPECTION

8.01 Purpose

The National Bridge Inspection Standards (NBIS) require each state to inspect underwater structural elements and to establish criteria to determine the level and frequency to which the members must be inspected. The regular inspection and evaluation of submerged components is vital in determining the overall condition of substructure elements, changes that may have occurred to channel conditions since the previous inspection, effective strategies to mitigate scour through the use of countermeasures, and the continued safe use of the assets by the motoring public. Since Michigan's National Bridge Inventory currently has 7,673 structures over water, comprising nearly 70 percent of the statewide inventory, it is important to implement correct and effective inspection techniques for the proper evaluation of the bridges. This chapter supplements the techniques, requirements, and inspection procedures provided in the FHWA *Bridge Inspector's Reference Manual* and AASHTO *Manual for Bridge Evaluation*.

8.02 Underwater Inspection Methods

MDOT accepts three techniques of underwater inspection which are classified as wade and probe, boat and probe, and underwater diving inspection. The method employed is recommended to be based according to the maximum variation measured from the normal water surface elevation to the channel bottom at areas adjacent to the substructure unit(s). The following water depths are general guidelines for selecting the appropriate method of inspection:

- Wade and Probe – Water depths of 4 feet or less
- Boat and Probe – Water depths of 4 feet to 10 feet
- Underwater Diving Inspection – Water depths exceeding 10 feet

Since cost and effort levels vary significantly amongst each type the method used should be approved by the bridge owner. When safety concerns arise the inspection team leader shall be responsible for documenting the issue on the inspection report and providing a recommendation to the bridge owner for an alternate means to complete the work. Situations requiring a delay may occur due to safety reasons caused by channel flow velocity, debris present, or other hazards.

MDOT policy requires all substructure components that are submerged in water at depths of ten feet or greater, measured from the normal water surface elevation to the channel bottom, to be inspected by an underwater diving inspector. Exceptions may be granted in writing by the Bridge Inspection Program Manager in particular cases where it is demonstrated that the boat and probe method is sufficient due to water clarity or other unusual features. For components that are submerged at depths ranging from four feet to ten feet it is the bridge owner's choice on whether to perform the inspection using the boat and probe or underwater diving inspection method. Factors for consideration in determining the

method that will be employed should include scour criticality, channel characteristics, substructure type and conditions, and historical data reflecting the necessity to utilize an underwater diving inspector.

Structure Inventory & Appraisal (SI&A) Item 176 Underwater Inspection should be reviewed to determine if the method of inspection has been accurately coded. If the coding is incorrect the inspection team leader or bridge owner shall adjust it accordingly. Structures that are not over water must be coded "0" to indicate that an underwater inspection is not required. All bridges requiring an underwater inspection are to have one of the following codes for Item 176:

1) Wade and Probe – Water depths of 4 feet or less
2) Boat and Probe – Water depths of 4 feet to 10 feet
3) Underwater Diving Inspection – Water depths exceeding 10 feet

8.03 Underwater Diving Levels of Inspection Intensity

The intensity of the underwater diving inspection will be dependent on the type of inspection performed and the observations noted throughout the process. There are three standardized levels that have been provided by the United States Navy to describe the effort required during an underwater diving inspection. All scheduled underwater diving inspections must begin at the Level I intensity with Level II intensity performed on a minimum of 10 percent of the surface area.

A Level I underwater diving inspection is a visual inspection conducted to detect deterioration of the substructure elements and to verify the presence of scour. The entire area exposed between the water surface and channel bottom must be inspected. Probing for scour should always occur if the diving inspector believes sedimentation has recently occurred or when the clarity of water does not permit sufficient observation of the channel bottom.

Level II inspections must be expanded when the findings indicate signs of deterioration that require further analysis. Representative samples of the substructure must be cleaned to remove algae or aquatic growth to permit the inspection on the portion of the components that were identified. The extent of Level II intensity shall be increased according to engineering judgment and the defects discovered.

When the results of the Level II inspection show advanced deterioration consisting of section loss, or other damage that cannot be detected through visual observation, further inspection and testing will be required for an analysis or the development of repair procedures. Level III inspections require non-destructive or partially destructive testing and result from suspected structural concerns.

8.04 Types and Frequency of Underwater Inspections

Scheduled underwater inspection types may be organized and initiated according to several factors such as age, design of the structure, previously observed conditions, and suspected rate of deterioration. Unscheduled underwater inspections are the result of human or environmental factors that could not be anticipated during the previous field examination. The inspection team leader must use the Request for

Action form as documentation and notification to the bridge owner whenever additional effort or increased intensity level is necessary to properly assess any concerns.

Initial underwater inspections are to be performed during the scheduled post-construction inventory inspection once replacement or significant rehabilitation of a structure has been substantially completed in locations where the water depths encountered are expected to be 10 feet or less. For new or replaced structures that are built where levels exceed 10 feet, the initial inspection work is completed during the construction phase. Verification that the structure has been constructed according to design drawings and specifications is documented through the submittal of MDOT form 1120 *Final Inspection/Acceptance and Certification Report*. Once opened to the public, an underwater diving inspection must be completed within 60 months of a bridge entering service or earlier at the discretion of the bridge owner/engineer. This initial inspection provides the baseline data that will be referenced in order to evaluate the deterioration of the materials during subsequent underwater inspections.

Routine underwater inspections are regularly scheduled and executed at frequencies dependent on the techniques that may be employed and previously observed conditions. At water depths of 10 feet or less an underwater inspection is often performed at the same frequency as the routine inspection and is completed by the inspection team leader using the wade and probe or boat and probe techniques. Where the normal water level exceeds 10 feet an underwater diving inspection must be completed at intervals that do not exceed 60 months, or 72 months with prior written FHWA approval.

Level II intensity shall be conducted on approximately 10 percent of the surface area inspected during the routine underwater diving inspection, and may be increased if sufficient defects are observed. Stream bed cross-sections must be completed at the minimum rate described in the MDOT *Guidelines for Bridge Inspection Frequencies* in order to determine if channel erosion or active scour is present during high flow events. Substructure components or elements of them, exhibiting signs of observed deterioration that do not affect safety must be noted so they may be referenced during the next inspection. When the underwater diving inspector identifies serious deterioration that may affect the structural integrity of the component the intensity of the inspection may be increased to a Level III for further investigation.

Unscheduled underwater damage inspections must be completed when there are problems reported due to vessel impact or any other cause leading to possible structural capacity affects. The degree of effort, level of intensity, and components reviewed will depend on circumstances that are unique for each particular event. The inspection may be limited to only include an evaluation of the protective systems or a single substructure element. However, if the limits of the damage are unknown it shall initially include a Level I to define the areas that have been impacted. Depending on the degree of damage, a Level II or Level III inspection may be required to verify severity or provide information for the design of remedial repair measures. If the safe load capacity is significantly affected or closures are implemented the incident is a critical finding and must be reported to FHWA.

In-depth underwater inspections may be initiated as a result of observations identified during a scheduled routine underwater inspection, deficiencies found during a damage inspection, or any other occurrence where additional information is required for further evaluation. There are also instances where bridge owners of complex or unique structures schedule a detailed appraisal for every underwater diving inspection in order to provide additional details for the important and costly infrastructure assets. In-depth inspections often begin with a substantial amount of the area being inspected at the Level II intensity in order to quantify the limits of deficiencies.

When a specific cause or event requires increased monitoring then a special underwater inspection must be performed. A special underwater diving inspection may be initiated when scour is suspected during high flow or other events. This type of inspection may be required at any time throughout the year, but occur most often after spring precipitation and snow melt runoff causes rivers to rapidly rise. The collection of debris around a pier or other element in the channel may cause localized scour due to the redirection of flow. When scour is verified, the RFA form with supporting documentation must be submitted for review to a hydraulics engineer. Special inspections may also be scheduled by the bridge owner for increased monitoring of localized deterioration or other factors where an inspection of the entire substructure is unnecessary. The Scour Action High Flow Event report and Scour Inspection Report in MiB^{RIDG}E shall be used to document the observations.

The underwater inspection frequency shall be assigned according to observed distress, scour criticality, and sound engineering judgment. Items that often lead to an increased frequency include changes in the condition of elements or channel since the previous inspection, observed scour, substructure design, and maintenance history. For instance, drilled shaft piers located in the channel may not necessarily require an underwater inspection as often as pier walls founded on spread footings if their conditions are identical. Recommendations for the inspection interval may be found in the MDOT *Guidelines for Bridge Inspection Frequencies.* The inspection team leader or underwater diving inspector is responsible for increasing the inspection frequency when component or environmental conditions warrant.

8.05 Underwater Inspector Qualifications

Inspection team leaders performing underwater inspections using the wade and probe or boat and probe methods do not require any other additional training or certifications than what is described in Chapter 1. However, additional training classes will improve scour comprehension in order detect effects before they become significant. Recommended courses offered by the National Highway Institute (NHI) include:

- FHWA-NHI-135085 Plan of Action (POA) for Scour Critical Bridges
- FHWA-NHI-135046 Steam Stability and Scour at Highway Bridges
- FHWA-NHI-135047 Stream Stability and Scour at Highway Bridges for Bridge Inspectors
- FHWA-NHI-135048 Countermeasure Design for Bridge Scour and Stream Stability

The NBIS requires underwater diving inspectors to complete an FHWA approved bridge safety inspection course or underwater diving inspection course prior to inspecting any structures in the national bridge

inventory, and they must have knowledge in bridge safety inspection. In addition to the requirements for the underwater diver, an individual that meets the NBIS team leader requirements must also be on site. One person can serve as both the diver and NBIS team leader if they meet the requirements. The FHWA approved courses offered by NHI for underwater diving inspectors include:

- FHWA-NHI-130055 Safety Inspection of In-Service Bridges (10 days)
- FHWA-NHI-130091 Underwater Bridge Inspection (4 days)
- FHWA-NHI-130091A Underwater Bridge Inspection (5 days)

All underwater diving inspectors are subject to the requirements specified under 29 CFR Part 1910 *Commercial Diving Operations*. For MDOT owned bridges, additional certifications and experience requirements are required to become prequalified in underwater diving inspection. The qualifications include certification by a nationally recognized authority such as the Professional Association of Diving Instructors (PADI) or Association of Commercials Diving Educators (ACDE) in the type of equipment that will be used for the inspections. Divers must also have three years of documented structural inspection experience with bridges or similar structures, and meet the requirements of an inspection team leader.

8.06 Underwater Inspection Procedures

Due to the extraordinary challenges and complex nature of underwater inspections, especially those that require an underwater diving inspection, proper planning and early identification of factors that may inhibit the work are necessary for a successful inspection. When consultants are secured to perform underwater inspections the bridge owner should make the entire contents of the bridge file accessible for them to review. This action will allow information to be provided that will benefit the inspection team leader or underwater diving inspection team, and also assist in the resolution of concerns prior to the commencement of field work. The diving inspection team should allow adequate time for proper planning and development of procedures that will aid in a safe and successful underwater inspection. When an underwater diving inspection is required the inspection procedures shall be adequately documented in MiB^{RIDG}E using the SI&A Item 92B Underwater Inspection Report.

8.06.01 Underwater Inspection Procedures – Bridge Owner Responsibilities

The bridge owner is responsible for ensuring that the underwater diving inspection is performed by qualified staff that meet the requirements outlined in the NBIS. Copies of certifications for the underwater diving inspector and inspection team leader must be retained by the bridge owner for future quality assurance or FHWA National Bridge Inspection Program reviews. Local agency bridge owners are recommended to comprehensively review the qualifications and experience of the underwater diving inspector and inspection team leader if the organization performing the inspection has not been prequalified by MDOT.

Inspections should be assigned a minimum of 30 days prior to the required inspection date. If the underwater diving inspection is to be performed by a consultant the bridge owner shall allow access to

the contents of the bridge file for review. Enough time should be granted to the inspection team for adequate review so proper steps may be taken during the planning and procedures development stages.

The bridge owner should review the work recommendations provided in the underwater inspection report for actions that will preserve the condition of the elements through maintenance, rehabilitation, or the implementation of scour countermeasures. If at any time during the underwater diving inspection a recommendation for an increased amount of Level II effort is requested then the bridge owner shall determine whether the additional work is necessary. Consultation with an experienced structural or hydraulics engineer for assistance in determining when the scope of work should be increased may be required.

8.06.02 Underwater Inspection Procedures – Inspection Team Leader Responsibilities

As previously described, the depth of water will have the greatest influence in determining the underwater inspection technique that will be utilized. For safety reasons inspection teams should be composed of two or more individuals when probing is performed. Diving operations must meet MiOSHA safety requirements. Open water diving operations typically require the underwater diving inspector to be assisted by a minimum of two tenders. Penetration dives require the same level of assistance included for open water dives but an additional diver must be in the water to assist the underwater diving inspector should complications occur.

Prior to performing any field work, the inspection team leader or underwater diving inspection team must review the entire contents of the bridge file and become particularly familiar with previous inspection reports, as-built plans, and stream bed cross sections prior to performing the dive. Special attention also needs to be provided to areas that were previously affected by scour, or where the underwater diving inspection report noted deterioration of the substructure components. This action will also aid the diving inspection team in identifying areas where Level II intensity inspections may be concentrated.

The Scour Plan of Action (POA), Scour Action Inspection, and Scour Action High Flow Event documents must also be reviewed for scour critical structures. The inspection team leader should provide recommendations to the bridge owner when improvements to the POA may be incorporated, and also review the information to determine where previous scour locations have occurred. The Scour Action Inspection Report must be updated following each diving inspection.

Before beginning an underwater diving inspection, additional needs have to be developed that are not required for either probing method. A dive plan must be created to identify roles and responsibilities throughout the inspection process. The diving sequence has to be described and include potential risks that may inhibit the productivity of the inspection. All safety hazards are to be considered and methods to mitigate their affects shall be determined. The level of inspection and methods to collect, measure, and record data will need to be deliberated prior to beginning any field work. Factors such as visibility, flow discharge, and the type of substructure units in the waterways will bear heavily on the complexity of the dive. The planning stage should also take into consideration all known information relating to the

waterway, use, and structural characteristics related to the components that will inspected. The underwater dive team shall also be responsible for determining if the waterway is navigable, whether Coast Guard permits are required, the depths that will be encountered, scour criticality of the components in the channel, and required diving equipment. Additional details are provided in publication FHWA-NHI-10-027 *Underwater Bridge Inspection*.

When the inspection team leader or underwater diving inspection team arrives at the structure, but prior to commencing the underwater inspection, an evaluation of the waterway shall begin. At a minimum this review shall include inspection for signs of bank erosion, evidence of channel migration, debris buildup, and obstructions that were not included on the previous inspection report. Deficiencies visually observed on the substructure above water will have already been included in the Bridge Safety Inspection Report (BSIR) if the underwater inspection is being performed during a routine bridge safety inspection, but they must also be noted in the underwater diving inspection report when the inspections are not performed concurrently.

The first task to be performed by the inspection team leader for either type of probing method is to review the area from the channel bank to determine if safety concerns are visible, a preferential access location, and to inspect the channel banks for signs of instability. Probing must occur along the entire length of all submerged substructure elements. The inspection team leader is required to update SI&A Item 61, Channel and Channel Protection, based according to the visible signs encountered.

When footings are included in the substructure design, the extent of examination must extend outside the limits of it to determine if scour or undermining has happened. When the channel bottom is above the top of footing, but the footing may be distinguished during probing, a comment shall be added to BSIR Item 13 Abutments or Item 14 Piers denoting the approximate depth of cover encountered.

Upon beginning an underwater diving inspection, the diving inspector shall follow the developed plan to determine if damage or deterioration is present on the submerged exposed surfaces of all components in the channel. A review of the structure, environment, and current conditions must be completed prior to diving.

Underwater inspections should verify whether scour exists and if defects are present. If the clarity of the waterway does not allow surfaces to be inspected visually the underwater diving inspector shall feel for irregularities on the surfaces of the elements. Deficiencies observed or detected above and below the water surface must be noted in the report for all substructure units that have surfaces submerged. All previous areas of concern should be reviewed on the underwater diving inspection report to confirm that they were inspected, and comments regarding their condition shall be included regardless of the assigned rating.

Chapter 13 of the FHWA *Bridge Inspector's Reference Manual* provides detailed information for deficiencies encountered for each material type. A summary of the common defects includes:

Concrete	Steel	Timber	Masonry
• Scaling • Cracks • Spalls • Exposed Reinforcement • Significant Delamination	• Corrosion • Loss of Section/ Holes • Cracks • Loose Connections	• Decay/Rot • Abrasion • Collision • Biological	• Cracks • Mortar Loss • Delamination

The approximate quantity and location of all defects shall be observed and documented to assign an accurate condition rating on the inspection report. Navigation protection systems and lights shall be inspected to determine whether they are functioning and any signs of deterioration rendering their effectiveness must be noted. SI&A Item 111 Pier or Abutment Protection (for Navigation) coding must be verified that it reflects current conditions.

In cases where probing does not allow for an accurate condition determination, the inspection team leader must notify the bridge owner so an underwater diving inspection may be scheduled.

When existing scour countermeasures are present they shall be inspected for effectiveness, defects, and damage. Riprap should be inspected for signs of displacement and disintegration. Cracks in armored channel are often negligent to overall performance, but wide cracks or spalls may lead to loss of material beneath the system and undermining. Separation or sagging of gabions and grout filled bags indicate the initiation of failure and reduced usefulness. Sheet piling that was installed as a scour countermeasure should be inspected to verify the extent of section loss and ensure adequate toe depth.

The elevation of the river bed relative to an established USGS datum must be measured for all structures over water. These measurements must be taken at the previous locations along the length of the bridge that is over the water and recorded on the *Stream Cross Section Report* form. This information must be compared to the previous data, if available, in the form of a graph.

8.07 Bridge Safety Inspection Report

For either probing method (wade or boat), which shall occur concurrently during the scheduled routine bridge safety inspection, the observations and deficiencies shall be entered on the BSIR. Ratings shall be assigned to the appropriate substructure or culvert items of the report according to the MDOT NBI Rating Guidelines. If shallow scouring of the substructure elements is observed the maximum rating that may be assigned to the piers or abutments is Fair. Scour that may affect the structural capacity shall be coded Poor, Serious, or Critical according to the proximity to the substructure and the extent of loss. The inspection team leader shall also update the following NBI ratings:

- BSIR/CSIR Channel and Channel Protection (SI&A Item 61)
- SI&A Item 71 Waterway Adequacy
- SI&A Item 111 Pier or Abutment Protection (only coded for structures on navigable waterways)

When scouring of the substructure elements cause a safety concern, the inspection team leader shall submit an RFA to the bridge owner for the installation of scour countermeasures. Protective measures for the detection of minor scour may be identified by a work recommendation provided in the report. For MDOT owned bridges, the bridge owner must contact the Design Division Hydraulics Engineer for recommendations regarding the type and design of countermeasure. It is recommended that local agency bridge owners secure a consultant with hydraulic design experience to perform the evaluation. See Chapter 6 for instructions on updating Item 113.

8.08 Underwater Inspection Report

An Underwater Inspection Report (UIR) shall only be completed when an underwater diving inspection is required. The contents of the report consist of the data that must be entered in the UIR using the MiB^{RIDG}E web-based system and the documents described in this section. Once the inspector selects to add a new underwater inspection report, all of the physical and condition information located in the header will automatically generate once it has been entered following the initial routine inspection. If any of the fields are blank the team leader may correct the data but must notify the bridge owner.

The Underwater, Special Inspection section includes fields for inspector name, agency/company name, inspection frequency, and inspection date. The inspection team leader name and agency/company name is automatically generated according to the username and login information entered. The inspector may modify the monthly inspection interval by changing the previously assigned value. Since the date of the inspection often varies from the date of entering the report the inspector must select the date that field work occurred from the auto-populating calendar.

The General Notes section allows the inspection team leader to input any additional information that cannot be entered elsewhere on the form. This may include an overall summary of the elements condition, comments regarding limiting factors that affected the inspection, or other remarks that are beneficial to document. When the inspection requires more than one day to complete, or when a follow-up visit must be performed by the inspection team leader that entered the most current report, comments shall be included in the field describing the cause.

A new section has been added to the electronic UIR for the dive inspection team to enter the inspection procedures. This field must include the pertinent bridge specific procedures and unique comments regarding actions that were required to facilitate the inspection. **All underwater diving inspections performed after October 31, 2014 must include bridge specific procedures for the inspection.** The procedures listed should include the significant steps that were taken prior to the dive. Items identified may include identification of the substructure units inspected, the type of equipment used, bridge file review, areas where Level II or III intensity will be practiced, confirmation that the United States Coast

Guard was contacted, sequence of inspection, and any other information that will beneficially affect future diving operations.

Navigation Protection Systems section allows the team to provide comments related to the type(s) of systems at the bridge. Selection boxes are included to identify the system(s) employed which include:

- Fender Timbers
- Berm
- Dolphins
- Other

Notes shall be included for impact damage or decay of the protective systems in the channel or attached to the substructure. Clearance measurements shall be provided for all structures located over navigable waterways and must be measured normal to flow between abutments or any existing protective systems. These measurements should be compared to the standard for navigation clearances provided on the United States Coast Guard Office of Bridge Programs web site. This field shall also note whether the navigational lighting is functional at the time of inspection.

When scour countermeasures exist the type and condition shall be selected in the Scour Protection section. For additional information concerning scour see Chapter 6. Common types that have been listed on the report include:

- Rip-Rap
- Grouted Rip-Rap
- Wire Enclosed Rip-Rap
- Grouted Bags
- Sheet Piling
- Articulated Blocks
- Old Bridge Abutment
- Other

Data concerning the weather encountered during the inspection and channel characteristics are provided in the Waterway and Weather Conditions section. Required fields that must be entered include current speed of the water velocity, turbidity during the dive, stream bed material, the maximum depth encountered, weather conditions on the day of the dive, air and water temperatures. The Marine Growth on Structure field also provides an opportunity to indicate whether algae, zebra mussels, or other aquatic organisms are covering the surface of the elements.

Dive team, equipment, access and safety concerns may be entered in the Inspection Staff and Equipment section. The engineer, underwater diving inspector, and tender names must be entered. The team leader entering the report must verity that a NBI certified diver was used. If the inspection requires a penetration dive to be performed it shall be indicated in the Safety Concerns field along with the name of the stand-by diver. Remarks concerning any other pertinent safety concerns discovered

throughout the inspection must also be noted. Selection boxes have been created for the dive equipment used as well as the nearest boat launch site.

The Inspection Details section provides several fields where information regarding the physical characteristics and condition of the substructure components may be identified. Observations concerning the stream bed channel and slope shall be entered in the Waterway and Bank Observations field. Data entry fields are also delineated for substructure observations above and below the waterline. Each specific element should be clearly defined with comments provided noting defects and approximate locations regardless of their condition. Since debris in the waterway may lead to localized scour effects comments regarding the extent and impacts observed at the time of inspection must be entered. Suggestions must also be included in the Recommendations field concerning the installation of scour countermeasures or changes to NBI coding for the bridge owner or previous routine inspection team leader to review. The inspector shall also indicate if video, photographs, site plan, and a stream bed profile have been completed.

The inspection team leader must always provide recommendations when scour is identified or for any submerged structural components that are rated in Fair or less condition. MiB^{RIDG}E has several preset options in the recommendations dropdown which includes an "other" recommendation type for activities that may be unique. The tasks must be assigned to a Low, Medium, or High priority and a description of the work shall be entered noting the location. A Scour Action Inspection report must be submitted in MiB^{RIDG}E for scour critical structures following every underwater diving inspection.

The UIR must consist of all the data observed and recorded during the inspection and create a report for the bridge file. This must also include a copy of the completed underwater Diving Inspection Report (UIR) and Scour Action Inspection Report (if applicable) that was created using the MiB^{RIDG}E web-based system with written information that identifies the following:

- Staff Qualifications
- Levels of Inspection
- Physical Characteristics
- Quantity of Components Subject
- Scour Countermeasures
- Proposed Maintenance or Rehabilitative Measures
- Deficiencies Observed
- Stream Cross-Section Report
- Substructure Drawings with Sketched Defects

The underwater diving inspector must also provide the bridge owner with recommendations for updating the following NBI ratings:

- Item 60 Substructure Elements
- Item 61 Channel and Channel Protection
- Item 71 Waterway Adequacy

- Item 111 Pier or Abutment Protection
- Item 113 Scour Critical Bridges (Observed conditions only)

A minimum of one hard copy report shall be provided to the bridge owner for each underwater diving inspection. An electronic copy of the contents shall also be included in Portable Document Format (PDF).